Gravity manipulation

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In chapter 6.5 we learned that in space particle dualism theory, gravitational acceleration is given by:

$$g = \frac{G_{|\mathbb{Y}|}\,|\mathbb{Y}|\,|\mathbb{y}|}{m\,r^2}$$

Here the ratio between the mass m and the quark count $|\mathbb{y}|$ of the test object depends on the material. For instance, iron falls at an ever so slightly faster rate than water, because there is a higher number $|\mathbb{y}|$ of quarks inside one kilogram of iron than there is inside one kilogram of water.

As we learned in chapter 6.4, this is because of negative binding energy. These tiny differences in gravity can be exploited to create gravity sensors that can tell what material an object of unknown density is made of simply by measuring its mass and the gravity it exerts. However, they are way too small to allow for any gravity altering technology.

One idea can be to have an electron plasma on board the spacecraft. Adding electrons to the spacecraft increases the mass, without increasing the quark count. However, considering how small the mass of electrons is, and the big charge they would accumulate, this is not very practical.

What if we change gravity not by adding non-gravitative mass, such as electrons, but by adding kinetic energy?

As we learned in chapter 6.6, if we want to calculate the relativistic SPD-gravitational acceleration, the Lorentz factor on the left and the Schwarzschild factor on the right cancel each other, because both are essentially the same factor, with the escape velocity as the value for v. This makes it seem as if mass inflation is irrelevant here, and as if relativistic corrections are irrelevant.

Let us imagine we have a spacecraft with gravity altering capabilities. Kinetic energy that is associated with the movement of our spacecraft as a whole cannot impact what happens inside that spacecraft, because uniform change to a frame of reference as a whole, is unnoticeable from within. It leads to some amount of time dilation, but it cannot change the gravitational acceleration that the spacecraft is subjected to (see chapter 3.10).

Nevertheless, there are many contributors to kinetic energy, and so we can have kinetic energy that is associated only with the components of the test object. That includes the thermal energy of the

test object, as well as the energy of any internal moving parts, such as rotating components. This kinetic energy is not associated with the speed of the object; it is instead added to the mass directly, and should be treated as an intrinsic property of the test object.

Plasma approach

If we choose thermal energy as our way of inflating the mass of our spacecraft, then we would have to have a hot plasma on board. Heating up a gas inflates the masses of the particles of that gas, until the gas turns into a plasma state where nuclei and electrons are separated. That would provide a means of increasing the mass without increasing the particle count.

For obtaining a relativistic electron plasma where 10% of the electrons reach 86% of the speed of light, which is a mass inflation factor of 2, we need to heat up our gas to a temperature of 3 billion Kelvin.

Currently the highest temperature achieved by a fusion reactor is 160 million Kelvin, which was sustained for 20 seconds.[1] This is still a far cry from the 3 billion Kelvin our application would require. Achieving and sustaining such high temperatures requires reactors that are always much heavier than the plasma that is being held in them. Since the fusion reactor itself is part of the whole system, and since its own mass is not relativistically inflated, it is not practical to try and alter gravity using fusion reactors. The only system that can maintain relativistic temperatures without the need for a container is a newly formed neutron star, but as we will see in the next chapter, neutron stars are dominated by gravitational binding energy, which plays a much more significant role in them than thermal energy.

Particle accelerators and storage rings

What if we use particle accelerators to inflate a significant portion of the total mass of our spacecraft?

In ordinary particle accelerators, the plasma accelerated inside is tiny in mass compared to the total mass of the accelerator. For our purpose we would have to have a significant portion of our total spaceship mass to be in form of plasma that is accelerated in tubes. Ordinary particle accelerators accelerate only small quantities of plasma because they need to avoid collisions between the particles of the plasma, so that it is not slowed down. However, if our goal is not to create new and interesting particles, but only to offset the balance between inertial and gravitational mass, then we do not need to reach the velocities typically reached by high-end particle accelerators. Reaching 86% of the speed of light will already be enough. If that is our goal, then it might be possible to accelerate very large quantities of plasma in our particle accelerator.

A problem that we face with classical particle accelerators is that they require magnets, and the larger the plasma inside is, the larger will the magnets have to be that accelerate the plasma. This makes it quite hard to not have the particle accelerator mass dwarf the mass of the plasma inside.

If we want to accelerate large quantities of plasma, we need large tunnels, with multiple concentric magnet rings, for the acceleration of the plasma. Those would be quite heavy, and thus not allow us to offset the balance between inertial and gravitational mass significantly.

A solution could be to accelerate the plasma in a classical particle accelerator, and to then store it in a storage ring.[1, 2, 3] Existing storage rings can keep particles in their magnetic tunnel ring on a constant velocity for many hours.

One way of keeping the storage ring-to-plasma mass ratio low is to a build structure of concentric proton and electron storage rings. Particles in each ring will be attracted to the particles in the last ring.

When large quantities of plasma are accelerated, then collisions will be more frequent, and thus the plasma would slow down rather quickly. This makes relying on re-accelerating on the ground quite impractical.

It turns out there are accelerators that do not use electromagnetic confinement at all.

Particle accelerators without magnets

Wakefield accelerators direct a laser beam into a plasma and thereby accelerate it. Different from an ordinary particle accelerator, the plasma can consist of particles of different types and charges. Another example is a particle accelerator that uses specially designed cavities to allow electromagnetic radiation to push particles forward. This type of accelerator is so small that it fits onto microchips.[4]

The disadvantage of both of these types of accelerators is that they are linear instead of circular, and so they don't allow us to store the inflated mass in order to have sustained altered gravity.

Hollow fiber glass wires as particle accelerators

How can we create a circular particle beam without the use of magnets? Optical fiber wires can guide laser light onto any trajectory. When light encounters an ordinary mirror, only $85 - 99.9\%$ of the light is reflected, the rest is absorbed. The smaller the reflection angle is, the higher is the amount of light that is reflected. In a fiber glass wire the reflection angles are always very small, and so there nearly 100% of the light is reflected. It is similar with electrons. A small scattering angle would allow electrons to bounce off the walls of a fiber wire without getting absorbed and without knocking out additional electrons.

Most optical fiber cables have a solid glass core. If we want to use optical fiber wires as circular wakefield accelerators, we need to keep both laser light as well as the plasma or gas that needs accelerating inside the fiber wire, and for that it needs to be hollow inside.

The Fiber Optics Group in EPFL's school of engineering has developed a technology to applify light inside hollow-core optical fiber wires. Their purpose was to both allow light to travel faster

and to reduce attenuation, which allows the light to keep its intensity over long distances.[5, 6]

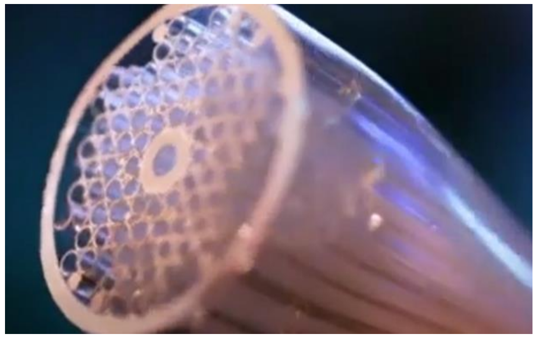

Fig. 151. hollow optical wires are normally used for allowing optical signals in them to travel faster while minimizing attenuation. We can repurpose them as wakefield particle accelerators.

According to the manufacturers, the laser beam can produce sound waves in the air inside the cables. If we form these cables into rings, then we should get a standing wave, and the gas particles would be accelerated enormously. One thing to take care of would be to not allow the cable to heat up too much from the collisions with particles from the gas inside.

However, this research was only about boosting signal strength, and so the wires were not circular, but linear.

The idea of using hollow fiber wires as particle accelerators is not entirely new. It has already been successfully implemented, by two researchers at the SLAC National Accelerator Laboratory in the US, Robert J. Noble and James E. Spencer, which tells us that it is feasible to use this for gravity manipulation.[7] Their paper cites three different phase velocities, $1.08c$, $0.93c$ and $1.004c$, as well as four group velocities, $0.6c$, $0.57c$, $0.58c$ and $0.93c$.

The first three group velocities refer to actual experiments, while the last one is a theoretical result referring to a different experimental setup. That means in current experiments, the group velocity is around 60% the speed of light. Anything beyond 85% will be enough for this application.

Aku Antikainen from the Photonics Center in Boston is exploring methods of optimizing this method of particle acceleration to reach group velocities close to the speed of light.[8]

However, Noble and Spencer did not use a circular configuration. Using such a configuration is necessary for maintained altered gravity, but it is challenging, because one has to prevent the accelerated particles from being absorbed by the inner walls of the wire.

Using xenon gas

For making it easier for the gas to dwarf the mass of the acceleration tube, we may be tempted to use the densest gases that exist, such as tungsten hexafluoride ($\mathrm{W\,F_6}$), but this is not feasible, because at high velocities surely the molecular bond will break, and then we are dealing with tungsten and fluorine separately, and we know that tungsten is only a gas at temperatures of $5{,}828$ Kelvin (5555 Celsius), and so all the tungsten would be smashed onto the walls, ending total

internal refraction for the laser beam, and only the fluorine would continue to be in a gaseous state.

At normal temperatures the densest gas is radon, but that is radioactive and it quickly turns into polonium, bismuth and lead. This also happens pretty quickly, and so it is not really an option for a practical device.

The second densest atomic gas is xenon. It has a density of only $0.0059\ \mathrm{g/cm^3}$ at standard temperature and pressure. Glass has a density of $2.4\ \mathrm{g/cm^3}$. So, to dwarf the mass of the container already before the acceleration process, the volume of the container has to be about 400 times greater than the volume of the solid glass.

Some elements have low boiling points. At its boiling point of 58.8 Celsius, bromine gas has a density of $0.00293\ \mathrm{g/cm^3}$, and Iodine $0.00676\ \mathrm{g/cm^3}$, at its boiling point of 184 Celsius. Considering that prior heating is necessary, not much is gained compared to using xenon.

Xenon shines brightly in the visible spectrum when accelerated, adding a compelling visual effect to its practicality.

Thin walls

The solid part of hollow core fiber wires is usually quite thick, and so one may think that it is quite hard for the mass of the accelerated gas to dwarf the mass of the wire.

It turns out that the thickness of the solid part of a hollow core fiber wire is not crucial to its functionality. There is no reason why the refractive index should have anything at all to do with thickness. The only reason the solid part is usually thick is for structural integrity, and because the usual applications does not require it to be thin. We can really make the solid part as thin as we want, and so then it is very easy for the gas inside to dwarf the mass of the solid shell.

Let's say the fiber wire is $7.4\ \mathrm{mm}$ thick, and the solid part is only $0.001\ \mathrm{mm}$ thick, which is enough to not let any visible light get through. Then, if we look at a $1\ \mathrm{mm}$ length of wire, the mass of xenon gas inside will be $0.99\ \mathrm{g/mm^3}$, while the mass of the solid fiber part will be only $0.0001\ \mathrm{g/mm^3}$.

These are ideal conditions to achieve gravity control through mass inflation.
Of course, in the below design there are thin filaments of additional walls spread throughout the hollow core, to better guide the laser light, but they are also very thin, and so in conclusion, it should be very easy to dwarf the mass of the wire.

Use of charge clusters

Ryan Hopkins expressed skepticism towards the idea of directly accelerating a dense plasma in a circular tube and proposed to instead accelerate charge clusters (Ryan Hopkins; personal correspondence; 20.10.2024). A charge cluster typically consists of $10^{11} - 10^{14}$ ions, which manage to stay together because of a special arrangement of spins. By arranging their spins in a specific way, the electrons can minimize their mutual repulsion, allowing them to cluster together.

However, this would require to be able to generate charge clusters reliably and in fast succession. While it is something that Ryan Hopkins himself works on, it seems unlikely that such a charge cluster generator would be light enough to not get in the way of allowing the gas mass to dwarf the accelerator mass.

Ionization

In wakefield accelerators, a laser beam ionizes the surrounding gas, which then gets accelerated by the wakefield that forms behind the laser photons. While photons do not have a charge themselves, laser light consists of many photons that are in a collective quantum coherent state. This basically means that there is a strong electromagnetic field associated with the laser photons that propagates with them, and that in turn allows particles to be accelerated in the wake of these laser photons.

While the acceleration itself does not require magnets, the fact that we are dealing with ions suggests that we could use some type of magnet to keep particles from hitting the inner walls of the fiber wire. To keep the additional mass at a minimum, we could use self-adhesive magnetic stripes. However, they would have to be attached to the outside of the fiber tube, because the laser light must be refracted on its inner surface in order for the laser beam to be contained inside the tube. Alternatives could include neodymium (Ndfeb) magnet powder, magnetic paint, rare-earth magnet foil, and ferrite magnet particles. Depending on the total mass, small magnets, or maybe even an extremely low mass electromagnetic coil could be used. As long as the purpose of the magnetic components is not to guide the particles but just repel them from the immediate inner surface, their mass won't grow proportional to the total rest mass of the gas, as would otherwise be the case.

Realstic hoverboards

If we want to use this technology to construct a real world-hoverboard, then we have certain limitations. For example, the mass of the hoverboard has to be larger than the mass of the person riding it. Therefore one cannot expect to be able to lift it off the ground using one's own bodily strength. That means thrusters have to be used both for forward movement, and occasionally for upwards movement, when the very slow descent brings the rider close to the ground. While off the ground, the rider can initiate various rotations of the board, which will appear slowed down when compared to flip rotations on a skateboard. The thrusters will only have to be activated when the board moves close to the ground or when it slows down in its forward movement. That means the board will appear to be levitating for most of the time.

Fig. 152. Hoverboard as seen in the movie “Back to the Future II” (1989).

If thrusters are used, then the board has to be larger, in order for the rider and the thrusters total mass to be smaller than the mass of the board. If we want to have a small board, then the rider needs to leap down from some altitude and then use lifts to get back up again.

Escape energy is still the same

The reader may think that being able to alter escape velocities will make space flight immensely cheaper. Unfortunately, that is not the case. When we enter the escape velocity into the classical kinetic energy equation, then we find that m cancels out:

$$E = \frac{1}{2}\, m \left(\sqrt{\frac{2\, G_{|\mathbb{Y}|}\, |\mathbb{Y}|\, |\mathbb{y}|}{r\, m}} \right)^2$$

$$E = \frac{G_{|\mathbb{Y}|}\, |\mathbb{Y}|\, |\mathbb{y}|}{r}$$

And so, we see that when the numbers of quarks $|\mathbb{Y}|$ and $|\mathbb{y}|$ involved are the same, then the energy required to reach the escape velocity is the same, regardless of the mass of the objects.

So, takeoff in this special chromogravity spacecraft will not save us any energy. It also would not look any different from the takeoff of a normal spacecraft. Landing on the other hand would look quite different, as the freefall speed would be significantly altered.

Acceleration force is still the same

We do not escape Earth with a single throw, and so the escape velocity is not really the right thing to look at when we want to know how much energy we need to escape Earth on a chromogravity spacecraft. We know that no spacecraft in history has ever reached the escape velocity of Earth ($11\ \text{km/s}$). Spacecrafts escape Earth through continuous thrust. It is therefore better to look at the energy needed to counter the downward acceleration at each moment in time.

In Newtonian gravity, Earth acceleration is given by $g = GM/r^2$. In space particle dualism it is:

$$g = \frac{G_{|\mathbb{Y}|} \, |\mathbb{Y}| \, |\mathbb{y}|}{r^2 \, m}$$

If we inflate the mass m without changing the quark count, then this will make g smaller, but since the force needed to counteract gravity is given by $F = g\,m$, and since g and m change interdependently, the required force is still exactly the same.

When we plug our gravitational acceleration formula into the classical force formula, we see that 'm' disappears again:

$$F = \left(\frac{G_{|\mathbb{Y}|} \, |\mathbb{Y}| \, |\mathbb{y}|}{r^2 \, m}\right) m$$

$$F = \frac{G_{|\mathbb{Y}|} \, |\mathbb{Y}| \, |\mathbb{y}|}{r^2}$$

That means the force needed to push against the downward acceleration depends only on the number of quarks inside Earth and the test object, and is not influenced by the mass of the test mass, nor the mass of Earth.

So, we do not gain anything from altering Earth acceleration when we just want to leave the Earth. Gravity also still decreases with the square of the distance, and so nothing changes in that regard either.

Impact velocity is still the same

Falling slower also does not help soften our landing. If we have half the acceleration for double the time, then our final velocity is unchanged.

Having more time to counteract the fall, also does not reduce the required energy consumption. A Space-X rocket spends about 5% of its fuel on the landing. This does not change even if we employ SPD-chromogravity.

Standing while falling

While we are accelerated downwards at the usual rate ($9.81\ \mathrm{m/s^2}$), our spacecraft is accelerated downwards at a much lower rate, and in a freefall situation, this would result in us being able to stand firm on the floor of the spacecraft, as if it wasn't falling. Also, all our items would remain in place, with no sign that the spacecraft is in freefall.

This would never happen in general relativity, where it is prohibited by the equivalence principle.

Increased movability

What would be the benefit of using this technology on Earth-bound aircrafts? If we reduce the gravitational acceleration enough, the flight patterns of any aircraft would quickly start looking

like it is actually levitating. It has to achieve its baseline altitude by traditional means, but after that, the aircraft would be able to stay in the air for a long time, even without wind or thrust.

It would still be falling, when it does not have thrust or wind, but it would do so at a much lower rate than regular aircraft, and when one adds thrust or wind to it, then the flight patterns of our aircraft or spacecraft would somewhat resemble that of UFOs in movies.

If our plasma inside the ship achieves particle speeds of 86% the speed of light, then half the spaceship being plasma is reasonable. If the plasma can be heated or accelerated to the level where the particles reach 99% the speed of light, then only about 1/7 of the ship needs to be plasma.

Saves energy used for staying above the ground

As we learned above, according to space particle dualism, we can reduce the gravitational acceleration felt by an aircraft or spacecraft, if we employ particle accelerators to increase the mass without increasing the quark count. This does not save us energy in terms of moving up and down in a gravitational field, but it saves us energy when we move forward. An aircraft will still use the same energy to get back up after dropping, but it will have travelled much further before it has to do that.

The increased mass will make it a little bit harder to accelerate forward, but if we are on a planet with no atmosphere, then this is not an issue, because we will have to reach our target velocity only once, and then we will keep that speed, because there is no air to slow us down. On Earth we have an atmosphere, and so we have to use the engines every now and then, in order to keep our velocity. However, the energy we use for keeping a constant velocity is just a small fraction of the total energy we need, most of which is the energy required to keep our altitude. Dropping slower means we have to get back up fewer times, and so we use less energy, to travel the same distance.

When we double the mass of our aircraft or spacecraft, without increasing the quark count, its surface area is unchanged, and so it still gets hit by the same many molecules in the air, but since we are heavier, they have much less of an impact on us.

What if we use a catapult, where maintaining an altitude is not part of its operation? Our chromogravity technology works by making the test object heavier, without increasing the particle count. While chromogravity allows us to stay in the air for longer, being heavier means that we cannot accelerate quite as much as before. Thus, we would not reach any further than before.

As we see here, this technology only makes sense if we drop more than once, and keep our forward impulse during that time.

Fig. 153. Fictional example for antigravity technology in the Star Wars franchise.

These are some more situations in which it is beneficial to use chromogravity technology:

Passing by a gravitational source

When one flies by a planet, one can get pass it without much course correction. In this case energy is saved. We can say that the spacecraft fell pass the planet, and so it did not need to get back up. The angle size of the deflection by the planet will depend upon the speed of the spacecraft, as well as the artificially altered value for the mass-gravity constant G and the mass-gravity acceleration g. This will even allow the spacecraft to pass by a black hole much closer than would normally be possible.

Fig. 154. Using chromogravity technology, a spacecraft could pass by a black hole much closer than normally possible, without falling in. [©2020 Eric Bruneton. GitHub project. Star data from Gaia DR 2 and Tycho 2.]

Levitating tables and sleds

When we use chromogravity technology to build levitating tables, the tables will be falling ever so slightly, but the falling happens so slow, that we can put things on it. That is something that we cannot do with a normal falling table, because without using chromogravity, everything will fall at approximately the same rate. Once the table has reached the ground, we can lift it back up and drop it again. If the Earth acceleration is altered enough, then this freefall will look like levitating.

Such tables could be used as sleds too, similar to 'anti-grav sleds' depicted in Star Trek.

Fig. 155. Fictional example for a medical anti-grav sled as seen in the movie “Star Trek – Into Darkness” (2013).

Using chromogravity for artificial gravity

If we use this chromogravity technology on spacecraft in orbit around Earth, then the astronauts inside the spacecraft will have a natural orbit around Earth that is different from that of the spacecraft; they fall at different rates. If the spacecraft falls around Earth with an acceleration that is smaller than the astronauts, they will be able to walk inside the spaceship.

Fig. 156. Chromogravity would make artificial gravity as seen in Star Trek entirely possible, although only during the time the spaceship is close to a gravitational source. [Illustration taken from Star Trek - TNG.]

Chromogravity can also be used for artificial gravity every time a spacecraft passes by a planet.

This means a chromogravity spacecraft can be designed with a clear floor-sealing-walls distinction. However, this also means that the part of the spaceship that harbors the crew should be rotatable against the thrusters, so that the floors of the spaceship are always oriented radially to the nearest gravitational source.

Fig. 157. The floors of a chromogravity spaceship would have to always be aligned radially to the nearest gravitational source, and thus the thrusters must be freely movable around the ship. [Illustration taken from Star Trek - Voyager.]

During periods of acceleration the thrusters can be beneath the floor, so that the acceleration can function as the artificial gravity. During that time chromogravity particle accelerators can be shut down.

Artificial gravity through rotation on the other hand requires a minimal radius of 900 meters, and thus is only feasible for incredibly large spaceships. It only seems feasible for a large space station.

Generalizing mass-gravity constants to in-frame relativistic mass

In this chapter we have already realized that the mass-gravity constant G does not only depend on the material, but also on the internal energy of the object. This sounds very much like general relativity, but it is quite different:

In space particle dualism, when we want to know the gravity between two objects, we weight them (measuring energy), and then we calculate the quark count in them, based on our knowledge of the material. In general relativity we only need to weight them, and then we know the gravity between them.

If we, on the other hand consider how much gravity a hypothetical physical object exerts, that will be very hard to calculate in general relativity, requiring complicated tensor equations, while in space particle dualism this only depends on quark count.

We recall the gravitational acceleration in its baryon number-based mass-gravity formulation (see chapter 6.5):

$$g = \frac{G_{\mathrm{p}}\, M}{r^2} \times \frac{B_1\, B_2}{\mu_1\, \mu_2}$$

Here B_1 and B_2 are the baryon numbers in the two gravitating objects, μ_1 and μ_2 are their masses in atomic units, and G_p is the mass-gravity constant of the proton. Incorporation what we learned in this chapter, we have to note that these masses should be the actual in-frame relativistic masses in atomic units, and so it is not enough to just look at the chemical composition to determine what

values for μ_1 and μ_2 we have to use. In-frame here means that the relativistic mass is not associated with movement of the frame of reference, but only with movement within the frame of reference, such as the temperature of objects, or movement of the equipment inside a spacecraft.

We can express this mathematically as:

$$g_\gamma \;=\; \frac{G_\mathrm{p}\, M}{r^2} \times \frac{B_1\, B_2}{\mu_1\, \gamma_1\, \mu_2\, \gamma_2}$$

We can formulate this in-frame relativistic mass-gravity acceleration also using a mass-gravity constant, as follows (see chapter 6.4):

$$g_{\mathrm{X}_\gamma} \;=\; \frac{G_{\mathrm{X}_\gamma}\, M}{r^2}$$

$$G_{X_\gamma} \;=\; G_\mathrm{H}\, \frac{n_{\mathrm{pX}}\, m_\mathrm{p} + n_{\mathrm{nX}}\, m_\mathrm{n}}{\gamma\, m_\mathrm{X}}$$

In most situations we can assume that $\gamma\, m_X \;\approx\; m_\mathrm{X}$, because unless we are dealing with a relativistic gas, mass inflation due to temperature will be minimal. The only other case would be particles that are accelerated inside particle accelerators. We do not normally deal with such situations, as relativistic gases are very unusual test objects for performing a Cavendish experiment, or a freefall experiment. A Cavendish experiment measuring the gravitational attraction between two particle accelerators would be even more unusual. And who would want to drop a particle accelerator in a vacuum, to see how it falls?

In nature we never deal with a falling relativistic gas, because in nature a relativistic gas would not be inside a container, and so we would only be dealing with individual gas particles falling, and in that case their kinetic energy is that of the whole system, which is why it cancels out in all equations (see chapter 6.6).

Implications for the Planck-like units

In chapter 6.9 we used G_H and G_n to create smallest possible Planck-lengths, but in this chapter, we have seen that it is possible to artificially create G-values that are even smaller than G_H and G_n. Does this mean there is no smallest meaningful scale?

No, G_H and G_n are based on rest masses, which are fundamental. Using a G-value that includes thermal or other internal kinetic energy for our Planck-unit would be like treating a relativistic mass as a fundamental constant. The fact that the relativistic mass of an electron changes all the time does not make the electron rest mass less fundamental.

Furthermore, G-values that are smaller than G_n can only be associated with a large number of particles, because a single particle cannot be assigned thermal energy, and it does not have components which can have varying kinetic energy. That makes it even more obvious that G_H and G_n are fundamental constants that are eligible to be used for constructing our SPD-Planck length.

It can help to call G-values without thermal or other internal kinetic energy in them 'G-rest-values'.

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